Technical Report for NASA Grant NAG5-8362
Theoretical Studies Of Microphysics of Marine Boundary-Layer Clouds

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This project is aimed at better understanding the role that aerosols play in altering the properties of stratus clouds. This interaction, termed the indirect effect of aerosols on climate, is a major subject of study since the radiative forcing involved may rival that of greenhouse gases, but may be of the opposite sign. Our goal was to create numerical models of the phenomena, test them with data, and thereby gain insight into the physical processes occurring. Below we list the papers that we have produced during this grant. We then discuss these papers.

Papers published since inception of Grant

1. "Effects of aerosols on cloud albedo: Evaluation of Twomey's parameterization of cloud susceptibility using measurements of ship tracks (A. S. Ackerman, O. B. Toon, J.P. Taylor, D. W. Johnson, PV. Hobbs, and R. J. Ferek) J. Atmos. Sci., 57, 2684-2695 (2000).
2. "Perspective: How pollution suppresses rain", (Owen B. Toon), Science, 287, 1763-1765 (2000).
3. "Reduction of tropical cloudiness by soot" (A.S. Ackerman, O. B. Toon, D. E. Stevens, A. J. Heymsfield, V. Ramanathan, and E. J. Welton, Science 288, 1042-1047 (2000).
4. "Cloud coverage enhancement and nocturnal drizzle suppression in stratocumulus by aerosols" (A.S. Ackerman, O. B. Toon, D. E. Stevens, J. A. Coakley, Jr.) Science, submitted, (2002).

Summary of results from papers:

Our papers to date have focused on links between field programs and numerical models. In paper 1 above, we used data from a field program to investigate whether Twomey's mechanism did work in marine stratus clouds. We found that comparisons of

ship track and clouds around ship tracks had the relations predicted by Twomey's simple model between cloud particle numbers, cloud particle size and cloud albedo. However, we also found that there were other phenomena than considered by Twomey that were occurring in the clouds, and need to be considered in cloud models, such as changes in cloud thickness.

In paper 2 we described to the reader how several different mechanisms might lead to the suppression of rainfall that was reported in a companion paper in Science. This work has become the subject of considerable debate in the community since the data show that pollution from cities is suppressing rainfall, while the mechanisms I discussed provides possible explanations for the suppression.

Paper 3 is based on data from the INDOEX field program. Here we showed that the sooty aerosol that are so prevalent in Asia, can heat the air to such an extent that it may cause clouds to dissipate. Indeed the observed clouds in the hazy air appeared much less frequently than those in unpolluted air. Cloud burn off in this manner had never been identified prior to this paper.

Paper 4 shows that recent satellite data concerning the indirect effect of aerosols on clouds had been misinterpreted due to the filters applied to the data. Instead of showing liquid water content changing, the cloud fraction is instead changing. Our goal in this paper is also to determine the fractions of the albedo changes in these marine stratus due to the Twomey effect, to cloud fraction changes and to liquid water changes. We found that the Twomey effect dominates, while cloud fraction is also important. In contrast to the assumption made in many GCM climate studies, changes in liquid water path were not very important.